ROOT AND TOP GROWTH STUDIES OF FIVE BENTGRASSES
ON TEN SOIL MIXTURES

by

JOHN C. PAIR

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INTRODUCTION

Soil mixtures for golf greens have long been a topic of discussion but the controversy has recently been intensified by the most accelerated pace in golf course construction since the introduction of the game into the United States.

One reason for the failure of previous recommendations is that more golf is being played than ever before and the greens are having to demonstrate a higher resistance to compaction than ever thought necessary.

When a soil is subjected to compaction, high moisture applications, and nutrient levels which accelerate the decomposition of organic matter, the physical properties are difficult to maintain in a condition which is conducive to good turf grass growth.

One method for overcoming this undesirable change in soil structure is to create a mixture which will resist the effects of compaction under these adverse conditions and yet possess such qualities as are necessary to produce turf with a desirable playing surface.

This investigation evaluates ten experimental soil mixtures to determine the sand-soil-peat ratio which is superior for the foliar and root development of five bentgrass varieties.

REVIEW OF LITERATURE

In the selection of a soil mixture to be used in the construction of a golf green there are a multitude of factors to be considered. The mixture should be of such a nature that it will allow quick drainage, yet hold water and nutrients, resist compaction and maintain its porosity to air and water after extended periods of play and possess a resilience that is suitable to the players.

Previous recommendations are being replaced by a trend toward unusually high sand proportions. Latham (21) reports that, generally speaking, a desirable soil mixture should contain approximately 60 to 75 percent sand, 10 to 15 percent topsoil, and the remainder peat or some other organic material. Ferguson (10) recommends the use of 75 percent coarse sand, 15 percent peat and 10 percent heavy clay soil. The topsoil which is incorporated into the mixture deserves considerable attention. About five to eight percent pure clay is sufficient to permit the mixture to be fairly effective in supplying nutrients to the grass. A survey by Garman (13) showed that greens in Oklahoma containing less than three percent by weight of clay exhibited occasional chlorosis, poor growth, and moisture deficient areas. When the clay content of a mixture rises above 10 percent, it tends to become plastic in nature and the soil compacts readily. Howard (18) obtained best results, based on weight of clippings, from a mixture containing 5 to 10 percent montmorillonite clay.

The next consideration after determining the topsoil to be used is the grade of sand to incorporate. Kunze (19) (20), in working with mixtures of various size particles, found that after compaction the 1.0 to 0.5 millimeter and mixed particle sizes gave by far the largest clipping yield but the root weight increased with a decrease in particle size with the greatest quantity of roots in sands of the 0.5 to 0.25 millimeter range.

Howard (18) recommends a sand in which more than 50 percent of the particles are between 0.5 and 0.25 millimeter in mixtures containing from 5 to 10 percent clay. Goss (14) states that at least 70 to 85 percent by volume of a sand in the 0.4 to 0.2 millimeter group should be used in golf green mixtures.

Lunt (23) in California found that a four inch layer of sand placed on top of a soil susceptible to compaction would distribute the load of foot traffic sufficiently to effectively protect the soil underneath from compaction. The

most desirable sand size for this purpose appears to be in the range from 0.4 to 0.2 millimeter, with about 75 percent of the particles in this range and not more than 6 to 10 percent in the range smaller than 0.10 millimeter. Silt and very fine sand particles in the size group of 0.10 millimeter and smaller are too large to form aggregates readily, yet they are small enough to clog pore spaces and drainage ways among larger sand particles and soil aggregates. Soils with a silt content above 30 percent should be avoided in any construction program according to Goss (14).

In Oklahoma (1) there can usually be found a clayey sand containing from 10 to 25 percent clay with only three to four percent silt. This type of soil can very easily be supplemented by proper amounds of sand and organic matter to produce ideal proportions of each component.

Therefore, it is necessary not only to select a proper grade of sand, but to conduct a mechanical analysis of the topsoil to be used to obtain the amounts of sand, silt and clay which are contributed from this constituent.

In determining the type of organic matter to incorporate into the mixture, Richer (27) concluded that a mixture of a dynamic material which decays readily and aggregates silt and clay plus a material resistant to decay for long lasting effects would be desirable. Sprague (30) (31) states that cultivated New Jersey peat and raw Michigan peat were the most effective sources of organic matter based on the relative resistance to decay and sustained improvement in the physical condition of the soil.

Even though every component is present in the right amounts, proper and thorough mixing cannot be overlooked. It is in general agreement that "off the site" mixing is much to be preferred to "in place" mixing. Latham (21) demonstrated that golf greens constructed by applying the required materials to the soil and mixing with a rototiller or disc have resulted in a layered

condition which interferes with water penetration and root growth. This phenomenon was confirmed by Lunt (23) who showed how a distinct layer of coarse sand in a fine textured soil acts as a barrier to the movement of water.

Sand layers in greens and destruction of large pores by compaction, coupled with frequent irrigation, combine to produce soils that are almost saturated with water and poorly aerated. Diffusion measurements were made by Lunt (23) in a number of both good and poor quality greens and in most cases no measurable air movement at a depth of two and one-half inches below the soil surface was detectable. Air diffusion rates were invariably more rapid when similar tests were made just off the green in less compacted soil.

Gaseous exchange as well as water drainage is directly related to the porosity of the medium. More important than total porosity is the graduation and continuity of pore sizes (20). Small pores act as water reservoirs for the plant; whereas, large, or noncapillary pores, are needed for the diffusion of gases and removal of excess water. It is these latter pores which are usually deficient except in very sandy soils or soils with excellent structure, in which case aeration is reduced and root respiration is impaired followed by a resulting reduction in overall plant growth. These soil-air and water relationships affecting root development and penetration are discussed by Roberts (28).

In laboratory tests, Lunt (23), using soil columns, indicated that soil mixes containing 80 percent sand could still be compacted so that percolation rates became quite low, but this was not possible when using 90 percent sand. Laboratory methods have been standardized by Ferguson (8) and co-workers for the proper evaluation of putting green soil mixtures.

A few disadvantages of high sand content greens are the extra care involved in establishing the grass and applying the additional fertilizer which

is normally supplied by the soil. This may involve frequent fertilizing or the use of low solubility fertilizers which do not leach rapidly. Lunt (23) states that the fertility management of the experimental green at UCLA has not been difficult and that in view of the greater root depth which can be expected in sand greens, the frequency of irrigation might even be less than that of a typical green in which root development is limited to the upper few inches. Two irrigations per week during hot weather have been ample for the sand green there.

Nelson (24) reports that bentgrass, growing on a six inch layer of 95 percent sand, exhibited surface characteristics about equal to the plots on a sandy loam and proved to have deeper developed root zones. A disadvantage was a collapse of the soil plugs when changing golf cups.

In the proper evaluation of plant growth, it is necessary not only to observe the above ground portions but also make a thorough study of the quantity, depth and distribution of the root systems. The root systems of plants have received less attention than top growth largely because the latter are more conspicuous, have definite economic value in many crops, and form an easily available source of material for analysis. Since Stephen Hales (26) in 1727 perceived the idea that the quantitative extent of root systems had a direct bearing upon the productiveness of plants, strenuous efforts have been made to unveil the underground picture of plant life.

Much of the work on this subject during the past half century is reviewed by Weaver (35) and Pavlychenko (25). Until 1921 when Fitts (11) recognized the need for study in this field, very little consideration was given to the roots of turf grass. Since many questions regarding the management of turf seem to be directed towards the roots, more recent studies have been made by Sprague (32), Stuckey (33) and Burton (5).

Many attempts have been made to study roots in water cultures and various containers but results obtained under such highly artificial conditions do not illustrate the usual extent, shape, penetration, branching and performance of root systems grown in their natural habitat (26).

Brink (4) concluded that some method of direct observation under turf conditions would be highly desirable. This has been accomplished most generally by obtaining and washing soil plugs of actively growing turf. Burton (5) obtained cores eight feet deep and after washing the soil from the roots reported the yield in terms of depth and pounds per acre of oven dry roots. The oven dry weight basis is used by Sprague (32), Graber (15), and Davis (6), but Robertson (29) compared root systems also on the basis of volume displacement in water. Harrison (16) measured the oven dry weights of roots and also showed the bulk of roots under each treatment. The total number of roots, branching characteristics and vigor was studied by Frazier (12). Thus it is possible to express the quantity and growth habit of root systems in many different ways depending on the method of analysis and the type of data desired.

METHODS AND PROCEDURE

Since no extensive experimental work has been done in Kansas on soil mixtures for golf greens, it was thought advisable to use the available sand and topsoil from the Manhattan area in order that recommendations for golf courses would apply to the surrounding area as well as other states which have a similar soil type.

A mechanical analysis by the Bouyoucous hydrometer method (3) of the topsoil from the area on which the green was constructed indicates approximately 24 percent clay, 58 percent silt and 18 percent sand. The high silt content presented a serious problem because of its obvious affect on drainage and air

diffusion, nevertheless, it was decided to utilize this soil and attempt to find a soil-sand-peat ratio which would produce optimum root and foliar development of bentgrass and yet be resistant to compaction.

Selection of a Sand

Samples were obtained of five available sands and gravel from the Kansas (Kaw) and Blue Rivers and each was sifted through a series of sieves to separate the particles into size groups. Table 1 shows the analysis of the available sands and the gravel placed beneath the mixture for drainage.

Table 1. Sieve analysis of sands and gravel used in the green.

Size of Particles	Percent by Weight in Each Size				
	Kaw Blow Sand	Kaw Mason Sand	Kaw Concrete Sand	Blue Mason Sand	Blue Road Gravel
2.0 mm and larger	0.0	.4	15.2	0.0	64.4
1.0 - 2.0 mm	.4	7.7	19.0	19.4	25.4
0.5 - 1.0 mm	18.4	30.4	27.4	48.9	8.7
0.25 - 0.5 mm	68.8	50.4	30.6	26.2	2.1
0.105 - 0.25 mm	11.2	9.5	5.4	3.5	.3
less than .105 mm	1.2	.9	.7	1.3	.4

The blow sand from the Kaw river was found to be most similar in its range of particle sizes to the sand used in the experimental green at UCLA and recommended by Lunt (23) as being the most desirable grade of sand. He suggested the use of a sand having 75 percent of its particles in the .2 to .4 millimeter size with not more than 6 to 10 percent smaller than .1 millimeter. The Kaw blow sand most nearly conforms to these specifications and, therefore, was selected for comparison in these tests.

Kunze (20) and Dunning (7) recommend the use of larger sand particles in the .5 to 1.0 millimeter range. Dunning (7) states that sand having 80

percent of its particles in the .5 to 1.0 group with less than 20 percent being from .25 to .5 millimeter is the most desirable grade. The sand most closely resembling these specifications was Blue river mason sand. Therefore, it was chosen as the second sand for comparison.

Construction of the Green

Procedure for the construction of the green followed closely the specifications given by Ferguson (9) (10) and Holmes (17). The topsoil for the green was graded off and stockpiled near the mixing site. The subgrade was established on a gentle slope to the east and south just as the finished surface was to be. Road gravel of the type shown in Table 1 was spread at a depth of three inches to provide for drainage. Twelve inches of the soil mixtures were placed over the gravel. No coarse sand layer was included between the gravel and the mixtures due to the already high sand content of the mixtures. The only tile used in the drainage system was a six inch tile along the east edge under the collar of the green to facilitate the removal of excess water and prevent seepage through the collar.

Since the current recommendations are now in excess of 75 percent sand, it was thought that mixtures containing from 65 to 100 percent sand would constitute a satisfactory interval to include the maximum and minimum quantities which could be used in the construction of golf greens, and offer a fair comparison of various gradations in between.

The ten soil mixtures used in this test were formulated from the topsoil on the site, the two selected sands and a sphagnum type of coarse, poultry grade, unshredded, Canadian peat. The volume proportions of each mixture appear in Table 2.

Table 2. Volume proportions of soil mixtures.

No. of Mix	Type of Sand Used	% Sand	% Soil	% Peat
1	Blue River Mason	75	15	10
2	Kaw River Blow	75	15	10
3	Blue River Mason	65	20	15
4	Kaw River Blow	65	20	15
5	Blue River Mason	85	10	5
6	Kaw River Blow	85	10	5
7	Blue River Mason	90	5	5
8	Kaw River Blow	90	5	5
9	Blue River Mason	100	-	-
10	Kaw River Blow	100	-	-

The peat was available in four and six cubic foot bales; consequently, the sand and soil were also measured in cubic feet. A wooden box was erected with a capacity of 80 cubic feet. The materials were dumped into the box by means of a tractor with a front end loader. This was the only means of measuring the percentages of sand, soil and peat on a large scale. For example, 80 cubic feet of a mixture of 75 percent sand, 15 percent soil and 10 percent peat would contain 60 cubic feet of sand, 12 cubic feet of soil, and eight cubic feet of peat. An analysis of the soil mixtures was made after construction of the green to accurately determine the percentages actually contained in them.

The box was supported about three feet above ground in order that the contents could easily be shoveled out one end into a Royer soil shredder whereby the mixture was shredded and uniformly mixed before placing on the site of the green.

Each mix was in turn mixed and poured into forms three feet wide and 60 feet long made from 1 x 12 inch boards, except for the pure sand strips which required no mixing. This resulted in a soil layer 12 inches thick with a continuous three inch layer of coarse gravel underneath for drainage.

The 10 mixtures were arranged in a randomized manner and replicated three times in a split type of design, making a total of 30 soil strips each three feet wide and 60 feet long. The green therefore measured 90 x 60 feet plus a sloping border on all four sides on which to turn the greens mower and provide an apron for the green.

As each mixture was placed in the wooden forms it was settled by treading or "footing" until firm. Later the entire green was watered thoroughly to reveal any low spots and the surface was leveled by dragging back and forth along the mixtures but not across them so as to avoid mixing the top layer.

Establishing the Grass

Five strains of bentgrass, Agrostis palustris, were randomized and planted in strips perpendicular to the soil mixtures, thus providing a checker board arrangement of grass-mixture combinations. The green was divided in half and one replication of each variety was planted on both sides of the green, with the exception of Springfield and Carey. The varieties tested were Cohansey, Penncross, Seaside, Springfield, and Carey. The first three were duplicated; whereas, only one strip of the latter two were planted due to a limited supply of stolons. This resulted in a total of eight strips of grass each seven and a half feet wide and 90 feet long.

Hereafter, the term "plot" will be used to designate each 3 x 7½ foot grass-mixture combination and the sand-soil-peat mixtures will be referred to as simply "soil mixtures".

Penncross and Seaside were both seeded while Cohansey, Springfield, and Carey were all stolonized. Due to a delay in the construction of the green, the grass could not be planted until the week of April 27 - May 4. The method of stolonizing was a slight modification of the standard procedure now used on

golf greens. A steel door mat was used to hold the stolons while the top dressing corresponding to the soil mixture was applied to each individual plot.

Maintenance of the Green

All of the maintenance practices of mowing, watering, fertilizing, and spraying were conducted as nearly as possible to typical golf course conditions. The grass was mowed at one half inch starting on May 25 and was gradually lowered to one fourth inch where it was maintained throughout the remainder of the summer. Mowing was done three times per week through the month of June and was increased to six days per week during July and August.

The green was watered daily or as needed with a sprinkler supplemented by hand watering and syringing.

Fertility was kept at a high level by applying various soluble forms and organic types of fertilizers, adding trace elements occasionally, amounting to over 10 pounds of actual nitrogen per 1000 square feet by the end of the growing season.

A fungicide control program was followed consisting of P.M.A.S. and Tersan 75 applied as a preventative spray every 10 to 14 days. Panogen was later used instead and a snow mold prevention spray of Calo-clor was applied before the first cold period in the fall. Two sprays containing Dieldrin were applied during the season for the control of turf insects.

Crabgrass Control

A severe infestation of crabgrass on the green presented a serious problem, especially on the seeded strips of grass due to the late planting and warm temperatures which favored crabgrass germination during the early development of the bentgrass.

On June 21 and June 30 a spray of Disodinm methyl arsonate was applied at the lower dosage recommended for use on sensitive grasses. One and one-third pints in 30 gallons of water were applied each time to the 5400 square feet of bentgrass in the late afternoon when temperatures were well below 85° F. Fairly good control was obtained with two sprays and much of the crabgrass was completely killed but the third spray was withheld due to rising summer temperatures and the increasing danger of injury to the bentgrass; consequently, crabgrass continued to be a major problem throughout the growing season.

Technique of Evaluation

Each plot was visually rated at weekly intervals throughout the season from July 20, after the grass was well established, until growth ceased in November. Due to the difficulty in establishing the turf no attempt was made to compact the green either by rolling or actual foot traffic. All observations were based on the performance of the five grass varieties maintained under putting green conditions but without any play the first season. The most important consideration was the establishment of grass and the percent coverage obtained, but such factors as density of turf, invasion of other grasses such as crabgrass, and putting surface quality were also regarded. Watson (34) used the invasion of crabgrass and clover as an index to the quality of turf.

A rating system was devised on the basis of 1 to 10 to evaluate these qualities. Plates I and II represent a comparative example of the range from 1 to 10 used in rating the individual plots.

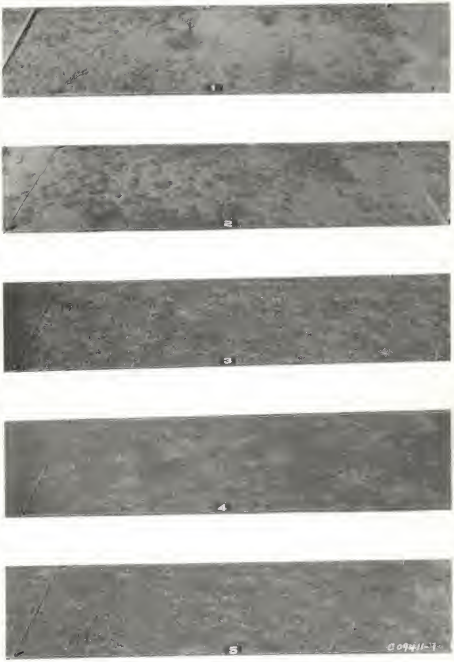
Root Studies

On July 1 preliminary steps were taken to observe differences in the root development of the grass on each mixture. One complete strip of Cohansey,

EXPLANATION OF PLATE I

A representative sample of five plots showing the respective values assigned to each in the evaluation scale from 1 to 10.

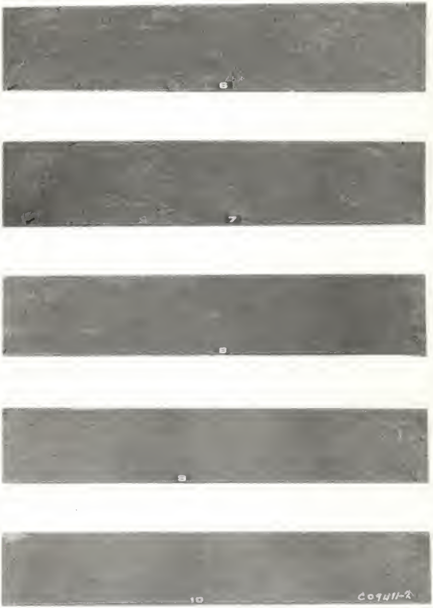
PLATE I



EXPLANATION OF PLATE II

A representative sample of five plots showing the respective values assigned to each in the evaluation scale from 1 to 10.

PLATE II



across three replications of soil mixtures, was sampled with an O. J. Noer soil profile sampler and the roots were washed on a 1/8 inch mesh hail screen but revealed no measurable difference in length. Very little difference in density was evident at this time.

Beard (2) reported that the seasonal growth of grasses is responsible for a shallower root system on bentgrass in the summer and deeper roots in the fall and spring. Therefore, more extensive studies were undertaken at the end of the growing season. From November 13 to 22, soil plugs were taken by means of a custom built profile sampler shown in Figure 2 of Plate III, which yielded a block of soil measuring 2 x 6 inches and 9¼ inches deep. A sample was taken from each plot in a densely covered area to minimize the error which would have been involved had the plots been plugged at random resulting in occasional plugs coming from completely bare spots or in crabgrass infested areas. All plots were sampled except those of the variety Carey which suffered considerable damage in August from disease, leaving some plots completely void of bentgrass.

Each plug was placed on an 8 x 12 inch piece of 1/8 inch hail screen and, after measuring root depth and thickness of thatch, was carefully washed with a fine spray of water, as shown in Figure 1 of Plate III. By soaking the root systems overnight all of the soil particles adhering after the first washing could be completely removed; however, the peat incorporated into the mixture could not be separated from the roots without causing considerable damage and consequently a reduction in yield. The contamination of root systems with peat and sawdust used in top dressing was also observed by Brink (4).

Therefore, it was necessary to devise another means of evaluating the quantity of roots from each treatment. After completing the sampling and washing operation, the root systems were spread out carefully to dry on paper

EXPLANATION OF PLATE III

Fig. 1. Washing sand and soil from the root systems of bentgrass by means of a fine spray of water.

Fig. 2. Profile soil sampler and sample of soil showing the design of the sampler and the relative size of the soil plug taken.

PLATE III

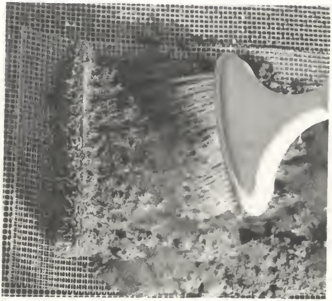


Fig. 1

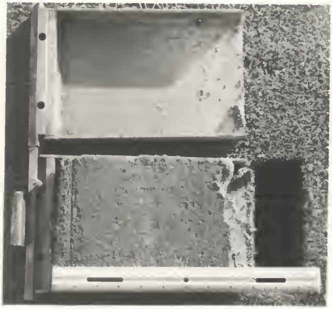


Fig. 2

towels in the greenhouse. Based on the density or the mass of roots, especially in the upper six to eight inches of the root zone, a rating system was established from 1 to 10 from which to score each individual root sample. This inclusive rating scale included the poorest or thinnest root development and also the most dense root system out of the 210 samples taken, with graduations in between to represent various degrees of density. Plate IV illustrates the arrangement of the root systems comprising the rating scale and the relative appearance of the root systems after washing and air drying.

Laboratory Procedure

Although the contents of the mixtures were carefully measured during the construction of the green, a test was conducted in the laboratory to determine the percentages of sand, silt and clay which were actually contained in the mixtures. This consisted of a mechanical analysis by the Bouyoucous hydrometer method (3) of a random composite sample from each of the 30 soil strips. However, the results obtained are reported on a weight basis; whereas, the constituents were each measured by volume.

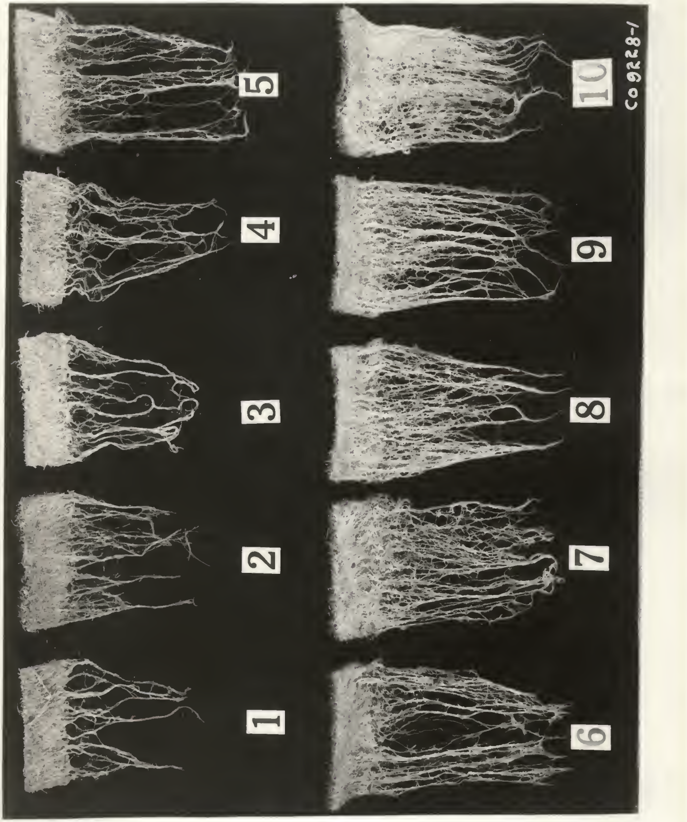
It appears to be a common practice to express the amounts of sand, silt and clay in the topsoil on a weight basis as determined by the Bouyoucous hydrometer method or the pipette and sieve procedure. Recommendations for the amounts of sand, soil, and organic matter to be included in a green are, however, nearly always given in volume quantities. Therefore, it becomes necessary to correlate the two units of measurement if they are ever to be used together in calculating and formulating various mixtures, or if one method of measurement is to be used in the mixing process and the other used to analyze the contents of the end product.

Samples approximating each mixture were carefully mixed in the laboratory using the same volume percentages of sand, soil and peat as were used in the

EXPLANATION OF PLATE IV

The arrangement of the root samples comprising the rating scale from 1 to 10 and the relative density, distribution and development of each.

PLATE IV



construction of the green. Bulk densities were determined for the two grades of sand and the topsoil in a loose condition approaching that prior to the mixing procedure used previously in the field.

The volume proportions of sand and soil were then measured by weight on an oven dry basis to insure accurate measurement of the percentages of each ingredient. The quantity of peat moss used in each mixture was measured by weight also, based on the bulk density of the peat in the bale.

Half of the samples were mixed including the peat moss and the other half were mixed omitting the peat moss to determine the effects of this organic material on the results of a mechanical analysis of the mixtures.

A mechanical analysis was conducted on each sample and correlations were made with results from previous mechanical analyses of random samples taken from the green in an effort to verify the actual percentages of sand, silt and clay in the soil strips mixed in the field.

An analysis of variance was conducted on all data to determine if any significant differences exist among replications, grass variety performance, density of root systems, soil mixtures, and dates throughout the growing season and for the purpose of making specific comparisons within varieties, mixtures and on certain dates during the summer.

Where the F test in the analysis indicated significant differences among treatments L.S.D.'s were calculated at the .05 level to detect the individual differences between means.

RESULTS

Visual Ratings of Plots

The design of the experiment is illustrated in Table 3, showing the replications of mixtures and grasses, and the totals of 14 ratings taken from

Table 3. Design of the experiment and sums of ratings on plots.

	Varieties of Grass								
Mix No.	Cohansey	Penncross	Springfield	Seaside	Penncross	Seaside	Carey	Cohansey	Reps.
7	77	58	107	24	50	31	55	96	Replication I
9	80	58	91	39	53	33	43	86	
5	98	58	118	60	74	62	62	115	
1	120	81	131	74	70	41	90	130	
10	102	78	129	80	56	51	106	134	
8	104	96	118	86	83	76	100	136	
6	122	95	105	72	59	78	107	136	
2	104	93	130	76	88	62	108	134	
3	105	93	117	70	86	64	79	114	
4	102	91	117	62	72	55	86	111	
5	99	92	120	77	77	69	64	119	Replication II
10	80	55	120	76	92	87	40	123	
6	111	72	113	65	78	73	83	120	
4	123	65	115	61	67	74	95	119	
8	99	68	109	59	75	66	81	102	
7	106	80	106	72	70	71	55	87	
3	120	62	96	52	62	58	76	101	
9	115	64	102	50	70	60	61	96	
2	131	59	104	48	56	54	69	123	
1	112	75	113	66	62	65	65	111	
10	107	93	107	83	93	84	66	95	Replication III
2	136	77	110	58	70	54	67	112	
5	110	85	102	58	64	68	69	108	
8	132	101	119	82	90	78	90	121	
9	120	77	101	73	85	70	79	107	
4	127	77	110	53	64	47	104	130	
7	121	91	105	60	71	60	85	102	
1	125	74	111	64	69	60	95	121	
3	114	74	95	55	62	57	88	111	
6	95	79	96	54	57	56	70	105	
Total	3297	2321	3317	1909	2125	1864	2338	3405	
$\bar{x}$	7.85	5.53	7.90	4.55	5.06	4.44	5.57	8.11	

July 20 to November 2 at weekly intervals, with the exception of September 1 to 15 when only one reading was taken.

The means ($\bar{x}$) of the grass varieties occur at the bottom of Table 3 and are shown in Table 4 along with the method by which the grasses were propagated. The statistical analysis of the data obtained from rating the performance of the grass on each plot revealed no significant difference between replications. With the exception of Carey, which suffered considerable damage from disease through the month of August, all stolonized grasses were significantly superior in their performance over the seeded varieties. No significant differences existed among the two replications of Cohansey and Springfield but of the seeded grasses, both replications of Penncross rated significantly better than those of Seaside, using the L.S.D. = .53 for the latter comparison.

Table 4.* Array of means of grass variety performance.

Variety of Grass	Mean	Method of Propagation
Cohansey	8.11	Stolonized
Springfield	7.90	Stolonized
Cohansey	7.85	Stolonized
Carey	5.57	Stolonized
Penncross	5.53	Seeded
Penncross	5.06	Seeded
Seaside	4.55	Seeded
Seaside	4.44	Seeded

*L.S.D. = .76 for comparing varieties

L.S.D. = .53 for comparing means of both replications of Penncross and Seaside

In an attempt to observe trends in the performance of the grass during the season, the means for all plots were calculated for each variety on the dates that observations were made. These figures are shown in Table 5, with an L.S.D. of .38 for making comparisons between grasses on certain dates.

Table 5.* Table of means for comparing varieties within various dates.

Date	Cohansey	Carey	Seaside	Penncross	Seaside	Springfield	Penncross	Cohansey
July 20	8.93	8.93	5.73	6.47	6.20	9.30	6.83	8.43
July 28	8.47	8.50	5.87	6.30	6.03	8.07	6.77	7.87
Aug. 4	8.3	7.37	3.93	4.83	4.20	7.40	5.37	7.63
Aug. 11	6.93	5.60	3.70	4.33	3.80	6.77	4.50	7.23
Aug. 18	7.17	5.13	4.20	4.67	4.13	7.07	5.27	7.17
Aug. 25	7.83	4.30	4.07	4.73	4.07	7.93	5.30	8.17
Sept. 1	8.07	4.37	3.90	4.47	4.17	7.83	5.30	7.87
Sept. 15	7.80	3.60	3.33	3.90	3.50	7.43	4.43	7.50
Sept. 23	8.27	4.07	3.63	4.50	4.07	7.97	5.07	7.87
Sept. 29	8.47	4.53	3.97	4.73	4.23	8.23	5.40	8.20
Oct. 6	8.30	5.00	4.47	5.13	4.73	8.10	5.80	8.00
Oct. 14	8.23	5.03	4.87	5.30	4.47	7.80	5.47	7.77
Oct. 24	8.37	5.70	5.13	5.50	4.70	8.17	5.80	8.17
Nov. 2	8.53	5.80	5.33	5.97	5.33	8.50	6.07	8.03

*L.S.D. = .38 for comparing varieties on a certain date or for comparing any one variety on various dates.

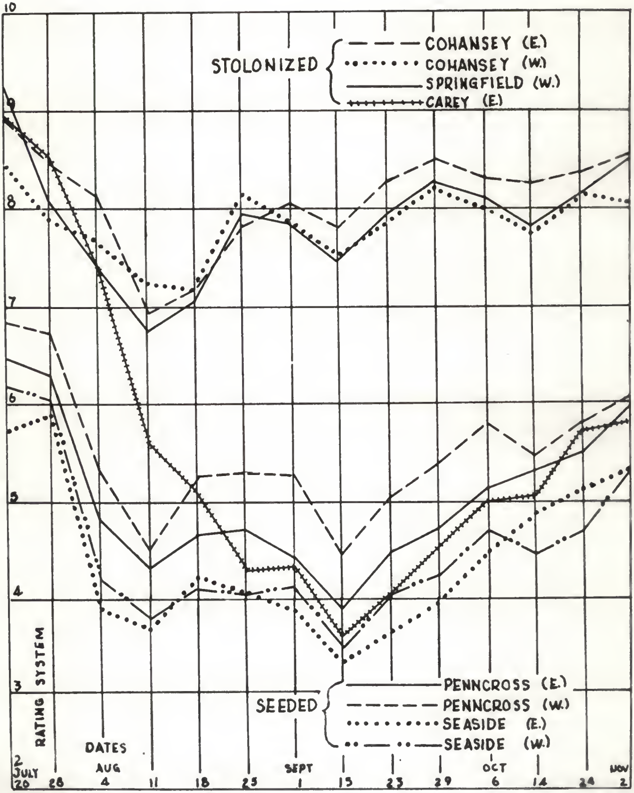
Plate V illustrates these trends in growth. With the exception of Carey the varieties conformed to a uniform pattern of growth with slight fluctuations between weeks being closely correlated with maintenance practices.

A revision was made in the rating scale on August 4 to provide a more strict system by which to evaluate the plots; consequently, the values for all plots were lowered which explains part of the decrease in the curve from July 28 to August 4 and the apparent overall decrease in quality from July 20 to the end of the season. However the revised scale only affected the seasonal curve and did not alter the relationship between grasses on any one date as can be seen from the graph. A more reasonable evaluation of the improvement in quality of turf can be seen from August 11 to November 2. The decrease in the performance from July 20 to August 11 was attributed to a combination of the revision in the rating scale plus chemical injury from spot spraying with Methar 30

EXPLANATION OF PLATE V

A graphic representation of the figures in Table 5 illustrating trends in the performance of grass varieties between dates throughout the season.

PLATE V


STOLONIZED
COHANSEY (E.)
COHANSEY (W.)
SPRINGFIELD (W.)
CAREY (E.)
SEEDED
PENNCROSS (E.)
PENNCROSS (W.)
SEASIDE (E.)
SEASIDE (W.)
RATING SYSTEM
DATES
10
9
8
7
6
5
4
3
2
JULY 20
28
AUG 4
11
18
25
SEPT 1
15
23
29
OCT 6
14
24
NOV 2

on July 22 and August 2 for the control of crabgrass. Descending fluctuations on September 15 and October 14 were correlated with possible injury due to unfavorable temperatures and possibly to the application of highly soluble fertilizers and fungicides.

Although some of the mixtures definitely supported a higher quality turf, the F test in the analysis of variance revealed no significant differences between mixtures during this first growing season. The significant differences between mixtures on certain dates, as is shown in Table 6, were evidently masked at the end of the season by the variation between dates.

Table 6.* Table of means for comparing mixtures on various dates.

	Number of Mixture									
Date	1	2	3	4	5	6	7	8	9	10
July 20	7.88	7.42	7.63	7.67	8.04	7.76	7.21	8.29	7.04	7.21
July 28	7.42	7.25	6.96	7.29	7.42	7.29	6.88	7.83	7.08	6.92
Aug. 4	6.04	6.17	5.88	6.25	6.17	6.38	5.62	6.75	5.71	6.12
Aug. 11	5.25	5.96	5.29	5.71	5.08	5.67	4.79	5.67	4.67	5.50
Aug. 18	5.75	5.79	5.25	5.79	5.54	6.00	5.08	6.17	4.92	5.71
Aug. 25	6.04	5.96	5.54	5.96	5.58	6.00	5.33	6.42	4.88	6.29
Sept. 1	6.08	5.75	5.50	5.83	5.58	6.00	5.04	6.54	4.79	6.33
Sept. 15	5.62	5.46	5.12	5.46	5.00	5.21	4.42	5.83	4.12	5.62
Sept. 23	6.04	5.96	5.54	5.88	5.42	5.79	4.62	6.62	4.62	6.29
Sept. 29	6.00	6.04	5.92	6.29	5.92	6.08	5.08	6.71	5.08	6.58
Oct. 6	6.45	6.50	6.08	6.46	6.04	6.08	5.38	6.88	5.54	6.42
Oct. 14	6.46	6.46	6.04	6.29	5.88	6.21	5.38	6.67	5.42	6.38
Oct. 24	6.62	6.75	6.50	6.71	6.29	6.54	5.71	6.83	5.71	6.75
Nov. 2	6.79	7.00	6.54	7.04	6.54	6.62	6.12	7.42	5.96	6.92
$\bar{x}$ of Mixes	6.32	6.32	5.93	6.33	6.04	6.25	5.48	6.75	5.40	6.36

*L.S.D. = .47 for comparing mixtures on some date or comparing a given mixture over all dates.
L.S.D. = .78 for comparing means of the mixtures.

Comparisons between mixtures on the same date may be made with the figures in Table 6 using the L.S.D. of .47 for determining significance. For

instance, considering each date separately, the number 8 mixture, 90 percent Kaw blow sand, was rated superior to the other mixtures every week with the exception of August 11, and was significantly better than most of the mixtures, especially the Blue mason mixes, as can be seen in Table 7.

Table 7. Mixtures which number 8 was significantly better than.

Date	Mixture number 8 was significantly better than:
July 20	2,3,4,6,7,9, and 10
July 28	2,3,4,6,7,9, and 10
Aug. 4	1,2,3,4,5,7,9, and 10
Aug. 11	5,7, and 9 (number 2 was significantly better than numbers 1,3,5,7, and 9)
Aug. 18	3,5,7, and 9
Aug. 25	3,5,7, and 9
Sept. 1	2,3,4,5,6,7, and 9
Sept. 15	3,5,6,7, and 9
Sept. 23	1,2,3,4,5,6,7, and 9
Sept. 29	1,2,3,5,6,7, and 9
Oct. 6	3,5,6,7, and 9
Oct. 14	3,5,6,7,9, and 10
Oct. 24	5,7, and 9
Nov. 2	1,3,5,6,7,9, and 10

A complete summary of the means of all observations taken on the plots occurs in Table 8. Each mean is based on data taken from 14 observations of three replications of each mixture or a total of 42 ratings. Using an L.S.D. of 1.14, comparisons may be made between grass varieties on the same mixture or between mixtures on which any one grass was growing.

Cohansey, in both replications, was rated highest on mixture number 2, 75 percent Kaw blow sand, both replications of Seaside grew best on number 10, 100 percent Kaw blow sand, and both Penncross strips performed best on number 8, 90 percent Kaw blow sand. Carey ranked highest on number 4, 65 percent Kaw blow sand, while Springfield resembled Seaside in that it thrived

best on 100 percent Kaw blow sand. Table 9 presents the first and second best mixtures for each variety of grass, along with the mixtures that these first two choices were significantly better than. The underlined numbers in the table indicate the second best mixture was also significantly better.

Table 8.* Means of grass varieties on soil mixtures.

Variety of Grass	Number of Mixture									
	1	2	3	4	5	6	7	8	9	10
Cohansey	8.62	8.79	7.76	8.57	8.14	8.60	6.79	8.55	6.88	8.38
Carey	5.95	5.81	5.79	6.79	4.64	6.19	4.64	6.45	4.36	5.05
Seaside	3.95	4.05	4.26	4.19	4.74	4.93	3.86	5.24	3.88	5.29
Penncross	4.79	5.10	5.00	4.83	5.12	4.62	4.55	5.91	4.95	5.74
Seaside	4.86	4.33	4.21	4.19	4.64	4.55	3.71	5.41	3.86	5.69
Springfield	8.45	8.19	7.33	8.14	8.10	7.48	7.57	8.24	7.00	8.48
Penncross	5.48	5.45	5.45	5.55	5.60	5.86	5.45	6.31	4.74	5.38
Cohansey	8.50	8.83	8.07	8.38	7.31	7.81	7.24	7.98	7.50	6.88

*L.S.D. = 1.14, underlined numbers are largest means.

Table 9. Significantly better mixtures for each variety of grass.

Variety of Grass	Rating of Mixtures				Significantly better than *
	1st	% Sand	2nd	% Sand	
Cohansey	2	75KB	1	75BM	7 and 9
Carey	4	65KB	8	90KB	5, 7, 9, and 10
Seaside	10	100KB	8	90KB	1, 2, 7, and 9
Penncross	8	90KB	10	100KB	6 and 7
Seaside	10	100KB	8	90KB	2, 3, 4, 6, 7, and 9
Springfield	10	100KB	1	75BM	3 and 9
Penncross	8	90KB	6	85KB	9
Cohansey	2	75KB	1	75BM	5, 7, 9, and 10

*The underlined numbers indicate the 2nd best mixture is also significantly better.

Of the eight strips of grass, five of them showed the highest or second highest rating on the number 8 mixture, 90 percent Kaw blow sand, and Springfield was rated third best on number 8, which is in close agreement with the figures in Table 6 where number 8 was rated highest among the mixtures 13 out of 14 dates.

With the exception of Carey, which grew most favorably on 65 percent Kaw blow sand and Cohansey which performed best on 75 percent Kaw blow, all of the grasses were rated highest on 90 percent and 100 percent Kaw blow sand. The second mixtures rated second best ranged from 75 percent to 100 percent including both sands. The number 1 mix, 75 percent Blue mason sand, was among the second choices three times. The most undesirable mixtures and the ones most often rated poorest significantly were numbers 7 and 9, 90 and 100 percent Blue mason sand respectively.

Root Studies

Table 10 constitutes a summary of the means of the ratings of the roots in samples taken from each plot on the green.

Table 10.* Means of root development based on a scale from 1 to 10.

Variety of Grass	Mixture										Variety $\bar{x}$
	75BM	75KB	65BM	65KB	85BM	85KB	90BM	90KB	100BM	100KB	
Cohansey	6.0	5.7	6.7	6.0	6.3	5.7	6.3	6.7	8.3	9.0	6.67
Seaside	6.3	6.3	6.7	6.0	7.0	6.7	6.7	7.3	8.3	9.7	7.10
Penncross	7.0	6.3	6.7	6.0	7.7	7.3	8.0	8.3	9.7	10.0	7.70
Seaside	7.0	6.3	5.7	6.3	7.7	6.7	7.0	8.0	8.7	9.7	7.30
Springfield	6.3	5.3	6.0	5.3	8.3	5.3	7.3	7.0	9.0	9.3	6.93
Penncross	6.7	6.7	6.7	6.0	8.0	6.3	7.0	8.3	8.0	10.0	7.37
Cohansey	5.3	7.3	6.7	6.3	7.0	6.0	6.7	6.3	7.0	8.0	6.67
$\bar{x}$ of Mixtures	6.4	6.3	6.4	6.0	7.4	6.3	7.0	7.4	8.4	9.4	

*The L.S.D. values are not all the same for each comparison due to the variation in the number of replications. They are as follows:

L.S.D. = .84 for comparing mixture means at bottom of table.

L.S.D. = .39 for comparing variety means, Cohansey vs. Penncross.

L.S.D. = .39 for comparing variety means, Cohansey vs. Seaside.
L.S.D. = .39 for comparing variety means, Penncross vs. Seaside.
L.S.D. = .48 for comparing variety means, Cohansey vs. Springfield.
L.S.D. = .48 for comparing variety means, Penncross vs. Springfield.
L.S.D. = .48 for comparing variety means, Seaside vs. Springfield.
L.S.D. = 1.2 for comparing grasses and mixtures within the table.
L.S.D. = .7 for comparing both reps of Penncross vs. Cohansey.
L.S.D. = .7 for comparing both reps of Penncross vs. Seaside.
L.S.D. = .7 for comparing both reps of Cohansey vs. Seaside.

Each mean is based on three plugs, one from each of the three replications of mixtures, using the rating scale from 1 to 10, as is illustrated in Plate III, to grade the density and distribution of roots in the $9\frac{1}{4}$ inches of soil sampled. The word "development" is used to describe these characteristics of roots such as density, distribution, extensiveness of development, and other qualities which are thought to comprise a well formed root system. Root length was not considered in the rating system because it was measured at the time of plugging and is presented in a separate table.

There were no significant differences between replications, but there existed a small degree of significance between grass varieties and large significant differences were apparent between mixtures. Significant differences between mixtures are arranged in Table 11.

Table 11. Significant differences of roots among mixtures.

Mixture	Significant over mixtures:
100KB	All others
100BM	All except 100KB
85BM and 90KB	65BM, 65KB, 75BM, 75KB, and 85KB
90BM	65KB
No significant differences between 65 BM, 65KB, 75BM, 75KB, and 85KB	

In comparing varieties, it can be seen from the variety $\bar{x}$ in Table 10 that the stolonized varieties, both replications of Cohansey and the strip of

Springfield, ranked significantly below both replications of Seaside and Penncross which were seeded. However, there was no significant difference between Seaside and Penncross or between Cohansey and Springfield. There is a general trend toward a more extensively developed root system as the sand content of the mixtures increases, with 100 percent Kaw blow rated first and 100 percent Blue mason considered second best.

For ease of comparison, these figures have been graphed in Plate VI to show how the development of roots varied with percentages of sand and grades of sand. The two replications of Penncross, Cohansey and Seaside have both been combined to present the average of the two.

Development of roots grown on mixtures containing Blue mason sand is illustrated in Figure 1 of Plate VI and root development of roots on Kaw blow sand mixtures is charted in Figure 2. These results are separated to indicate the similarity which existed between grass grown on the same percent and kind of sand and to illustrate the differences between growth of roots on different percentages and sizes of particles or grades of sand.

With the exception of Cohansey, all grasses growing on mason sand indicated a trend toward a more extensively developed root system as the percentage of sand increased, except in the 90 percent mason sand mixture wherein all varieties showed a downward fluctuation in root growth. Cohansey growing on blow sand mixtures exhibited its poorest root development in the 85 percent range. All of the other grasses showed increasing root development with increasing amounts of sand excepting Springfield which had no increase in root development on 65 to 85 percent sand but showed a marked increase on 85 to 100 percent sand mixtures.

The seeded grasses usually contained a more extensively developed root system than did the stolonized grasses, but the trends in growth on the various

EXPLANATION OF PLATE VI

Fig. 1. A graphic representation of the means of root development in varying percentages of Blue mason sand.

Fig. 2. A graphic representation of the means of root development in varying percentages of Kaw blow sand.

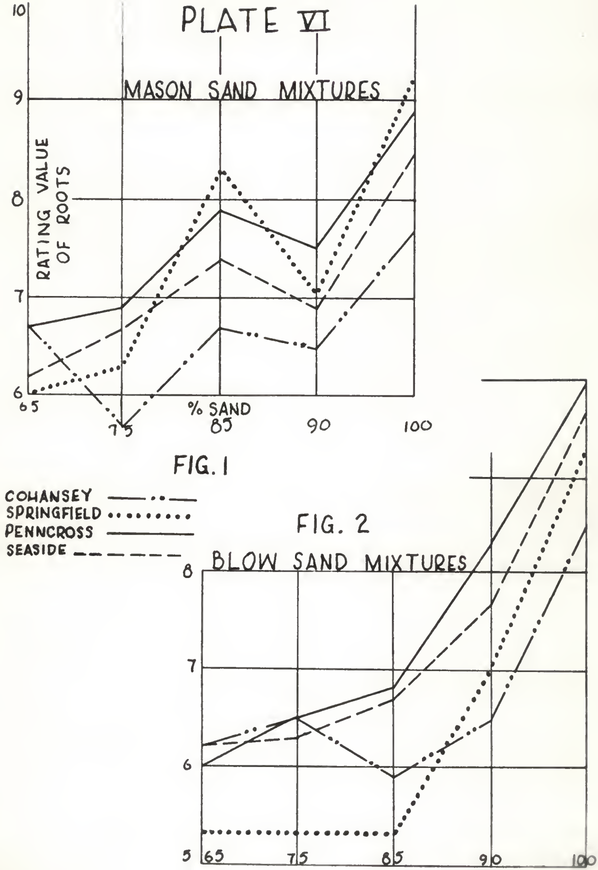


PLATE VI
MASON SAND MIXTURES
RATING VALUE OF ROOTS
10
9
8
7
6
65
75
% SAND
85
90
100
FIG. 1
COHANSEY
SPRINGFIELD
PENNCROSS
SEASIDE
FIG. 2
BLOW SAND MIXTURES
8
7
6
5
65
75
85
90
100

mixtures were quite close among varieties.

Among varieties, the means of root growth on all mixtures indicate superior overall growth on Penncross, followed closely by Seaside, with Springfield and Cohansey next in that order.

The totals of the means of all varieties, expressed in Plate VII illustrate the increasing root development in Kaw blow sand as the percent of sand increases from 65 to 100 percent, however, it is inferior to the development of roots in 65 to 85 percent Blue mason sand. Roots in the blow sand mixture surpassed those in mason sand at the 90 percent level where root growth decreased. The best root systems, based on these standards of evaluation, were observed in pure mason and pure blow sand, the latter being superior.

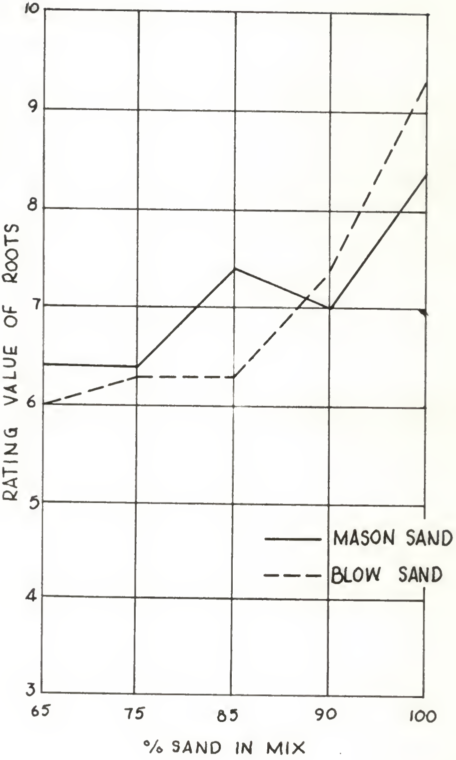
A representative sample from the 210 plugs taken is shown in Plate VIII to illustrate the relative comparison of root growth found in varying amounts of sand and in the two grades of sand. The odd numbers represent the roots growing in mason sand mixtures of 75, 65, 85, 90, and 100 percent sand respectively and the even numbers represent root systems of grass grown on blow sand mixtures of the same percentages. The reason for 75 percent coming before 65 percent in the numbering of the mixtures is because previous recommendations centered around 75 percent sand; therefore, this percentage was selected as a standard or model by which to compare others and was given the number 1. Varying percentages from 65 percent to 100 percent were then numbered consecutively as appears in all tables and graphs which refer to the mixes by number.

The root systems in Plate VIII were photographed shortly after being washed and before the statistical analysis was conducted. The representative samples were therefore based on incomplete figures and two corrections should

EXPLANATION OF PLATE VII

A graphic representation of the totals of the means of root development of all varieties of grass in varying percentages of Blue mason and Kaw blow sand.

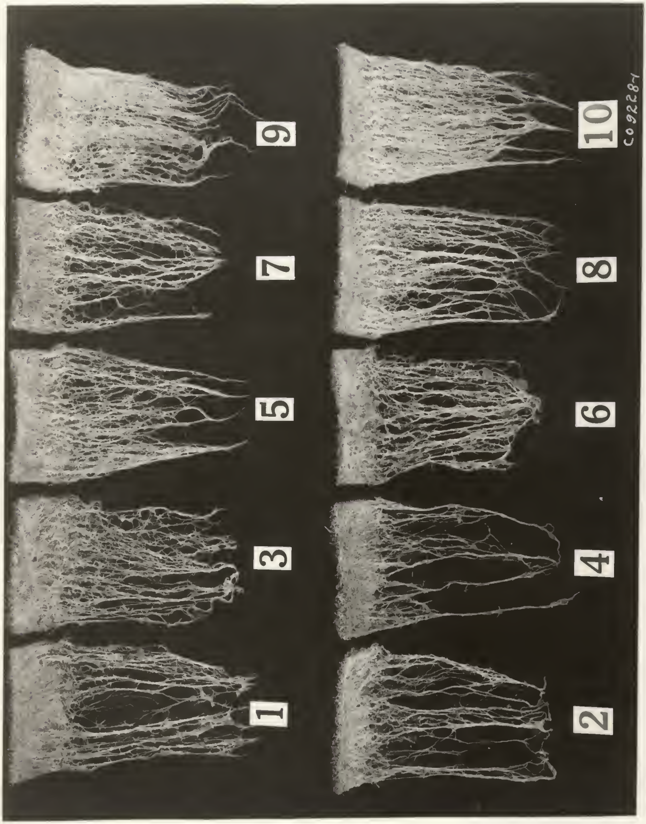
PLATE VII


10
9
8
7
6
5
4
3
RATING VALUE OF ROOTS
65
75
85
90
100
% SAND IN MIX
MASON SAND
BLOW SAND

EXPLANATION OF PLATE VIII

A representative sample of root systems taken from the plots of bentgrass. Numbers 1, 3, 5, 7 and 9 represent root development in the Blue mason mixtures of 75, 65, 85, 90 and 100 percent sand respectively. Numbers 2, 4, 6, 8 and 10 represent root development in Kaw blow mixtures of 75, 65, 85, 90 and 100 percent sand respectively.

PLATE VIII



be brought to view concerning the appearance of the root systems photographed.

The root systems shown in the picture are indicative of the average development of the roots of all grass varieties growing on the ten soil mixtures. However, number 3 appears to be superior to number 1 in the density of roots in the upper root zones, but according to the data in Table 9 and the graph in Plate VII these two were comparatively the same. Also numbers 2 and 6 should be identical in the photograph but number 6 appears to be more dense in the picture.

Despite these two discrepancies in the photograph, it is evident that generally the root systems became more extensively developed in the higher sand content mixes with the most fibrous system of roots in 100 percent blow sand, followed by the roots in 100 percent mason sand.

Number 8, 90 percent blow sand, proved to be superior to 90 percent mason sand for the development of roots, but 85 percent mason sand exceeded 85 percent blow sand in its production of roots, as is illustrated in Plate VII.

It will be well to note that the plots exhibiting superior top growth did not necessarily contain the best developed root systems. The visual ratings of the plots were based on a number of characteristics, among which coverage was the most important. However, the root systems were extracted and examined from a well covered area so the data from the root development studies should be considered as being based on root systems of equally well established turf.

Nevertheless, the plots which produced a more vigorous grass with more top growth, as on the heavier soil mixes, did not show the extensive root development that occurred in the sandier mixtures. Therefore, it seems that root development was closely correlated with the larger pore spaces and better aeration of the sandy mixtures; whereas, the amount of top growth depended for

the most part upon fertility and moisture conditions of mixtures containing higher percentages of soil and peat, in which extensive root development was not necessary for the uptake of nutrients and mosture as was the case of grass growing on sandy mixtures.

Root Depth

Root depth was measured at the time of sampling to determine any differences which might exist between varieties or between roots in various mixtures. The table of means of the root depth in centimeters is shown in Table 12.

Table 12.* Table of means of root depth of grasses on mixtures.

No. of Mixture	Variety of Grass: Cohansey (1)	Seaside (2)	Penncross (3)	Seaside (4)	Springfield (5)	Penncross (6)	Cohansey (7)
1	22.67	22.67	21.67	22.00	24.00	25.00	24.33
2	20.67	21.67	22.67	23.33	23.00	25.67	25.00
3.	22.33	22.00	22.00	23.67	24.00	24.33	24.33
4	20.33	22.67	20.33	23.67	24.67	26.00	24.67
5	20.67	21.33	22.00	20.33	25.00	25.67	23.67
6	21.00	22.33	21.33	21.00	24.33	24.33	22.67
7	20.00	21.00	21.67	20.33	25.00	23.00	23.00
8	19.33	23.67	22.33	20.67	24.33	23.33	23.67
9	20.67	25.33	22.33	25.00	24.33	25.00	22.00
10	19.33	25.33	23.33	24.67	23.67	25.00	24.33

*L.S.D. = 2.61 for comparing grass varieties on any one mixture or for comparing one grass on any of the various mixtures.

An analysis of variance showed no significant differences between replications or between mixtures, but indicated some degree of significance between grass varieties. Table 13 shows the array of means among varieties.

Table 13.* Array of means of root depth of grasses on mixtures.

Variety of Grass	Average Depth of Root System on all Mixtures
Penncross (6)	24.73 centimeters
Springfield (5)	24.23 centimeters
Cohansey (7)	23.77 centimeters
Seaside (2)	22.80 centimeters
Seaside (4)	22.47 centimeters
Penncross (3)	21.97 centimeters
Cohansey (1)	20.70 centimeters

*L.S.D. = 1.56

Mechanical Analysis

A comparison of the results of the mechanical analyses of the soil mixtures are shown in Table 14. The calculated figures in the first column were computed from the mechanical analyses of the two sands and the topsoil and the oven dry weight of the peat used in the laboratory sample. These calculations were used to estimate the percentages of sand, silt, clay and peat which could be expected in the sample. The mechanical analysis was conducted to show the actual percentages as determined by the Bouyoucos hydrometer method. (3) The amount of peat moss, however, is not measured by this method and, therefore, the weight of peat moss shown in the calculations is distributed among the other fractions of sand, silt and clay.

The bulk density of the two sands and the topsoil used in the laboratory mixtures are as follows: Kaw blow sand, 1.68 g/cm^3, Blue mason sand, 1.74 g/cm^3 and topsoil, .86 g/cm^3.

Table 14. Calculations and mechanical analysis of soil mixtures.

Mixture	Calculated Percentages				Laboratory Sample			Field Sample		
	Sand	Silt	Clay	Peat	%Sand	%Silt	%Clay	%Sand	%Silt	%Clay
65KB	86.48	7.75	4.04	1.74	89.6	6.6	3.8	85.1	9.9	4.9
65BM	86.93	7.77	3.87	1.69	88.2	7.8	4.3	84.6	10.5	5.1
75KB	90.41	5.32	3.18	1.06	92.2	4.8	3.0	87.4	8.4	4.2
75BM	90.76	5.43	3.03	1.03	91.0	5.6	3.5	88.8	7.1	4.3
85KB	93.73	3.28	2.46	.55	95.6	1.8	2.6	92.3	4.2	3.5
85BM	94.05	3.44	2.33	.52	93.6	3.9	2.5	92.2	4.7	3.2
90KB	96.03	1.60	1.86	.53	97.0	1.0	2.0	94.8	2.6	2.6
90BM	96.12	1.83	1.85	.51	96.1	1.7	2.3	94.5	3.0	2.6
100KB	--	--	--	--	98.7	0.0	1.3	98.4	.2	1.6
100BM	--	--	--	--	98.5	.3	1.2	97.9	.6	1.6

The percent by volume of soil used in mixing each laboratory sample was converted to percent by weight of the whole sample and appears in Table 15 showing the correlation between volume and weight proportions, based on oven dry soil with a bulk density of .86 g/cm^3. This correlation varies with the bulk density of the soil and these figures are only given here to illustrate the percentages of soil by weight and by volume used in the laboratory mixed samples.

Table 15.* Volume and weight proportions of topsoil in mixtures.

Mixture Sand - Soil - Peat	% Soil by Volume	by Weight
KB65 - 20 - 15	20	13.4
BM65 - 20 - 15	20	12.9
KB75 - 15 - 10	15	9.2
BM75 - 15 - 10	15	8.9
KB85 - 10 - 5	10	5.6
BM85 - 10 - 5	10	5.4
KB90 - 5 - 5	5	2.8
BM90 - 5 - 5	5	2.7

*Figures based on topsoil having a bulk density of .86 g/cm^3

DISCUSSION

Based on the data from visual observations of the performance of five bentgrass strains growing on ten soil mixtures, no significant differences existed between replications which strengthens the accuracy of the method devised to evaluate the plots and adds validity to the analysis.

The variety Carey suffered considerable disease injury during the month of August and, consequently, the ratings on this grass decreased at this stage of growth. However, the other two stolonized grasses, Cohansey and Springfield, were significantly superior in their performance over the seeded varieties of Penncross and Seaside. No significant differences existed among

the two strips of Cohansey and Springfield but Penncross was significantly better than Seaside in both cases.

This indicates the superiority of certain strains of grass but may also be due to the difference in the method of planting. Although quicker establishment may be expected from stolons, no conclusions may be drawn concerning which method of propagation is most desirable in this test because no one variety was planted both ways, due to the inherent genetic nature of the species. Each variety was propagated by its standard method and, therefore, direct comparisons may be made between varieties, regardless of the method of propagation.

Trends were observed in performance on the various dates observations were made. The grasses definitely conformed to a uniform growth curve among varieties but fluctuated with maintenance practices.

Although crabgrass infestation was more severe on the heavy soil mixtures, due to the topsoil being a major source of seed, it was thought that the infestation of this weed served as an index to coverage at the time crabgrass germination occurred. However, this resulted in a lower rating of the heavier soil mixtures at the end of the summer, but this was considered to be part of the normal maintenance problems of any golf green.

Nevertheless, no significant differences existed among soil mixtures, according to the F test, but some of the mixtures definitely supported a more favorable putting surface. The variation in mixtures between dates of observation apparently masked the differences between mixtures at the end of the season.

In comparing mixtures on certain dates throughout the summer, 90 percent Kaw blow sand was rated significantly better 13 out of 14 weeks. Table 7 represents the comparison of this mixture to the other mixtures on the 14

dates of rating. Frequently the 90 percent Kaw blow sand was significantly better than all of the Blue mason mixtures except 75 percent mason mixtures and was also rated significantly better than the other Kaw sand mixes in several instances. This is in close agreement with results reported by Lunt (23) who suggested the use of 85 to 90 percent sand of similar particle sizes possessed by the Kaw blow sand.

In comparing varieties on the various mixtures, Cohansey, in both replications grew best on 75 percent Kaw blow sand, both Penncross replications performed best on 90 percent Kaw blow sand and both strips of Seaside were rated highest on 100 percent Kaw blow sand. Carey seemed to thrive best on 65 percent Kaw blow sand.

The 90 percent Kaw blow sand was among the first and second choice of mixtures for five of the eight grass strips, which is in harmony with the reason this mixture ranked highest on its support of top growth 13 out of the 14 dates, and indicates the superiority of this mixture, especially for Penncross which ranked first on this mix in both its replications.

The close agreement between replication of the same grass variety on the same soil mixture encourages the choice of a specific mixture for each variety. The mixtures which ranked second in the case of Cohansey and Seaside were also consistent between replications which further adds to the evidence of the possibility of a specific varietal adaptation to a certain mixture.

Of the Blue mason sand mixes, the 75 percent sand was rated highest for the entire season, which is consistent with the recommendations given by Ferguson (10) using coarse sand of approximately the same particle size and percentage by volume. However, all of the Kaw blow sand mixtures were equal to or superior to the 75 percent Blue mason mixture with the exception of

85 percent blow sand, but these differences are not significant. Although the F test indicated no significant differences between mixtures for the most part, individual differences pointed out the 90 and 100 percent Blue mason sand mixtures to be significantly poorer than the other mixtures. Rapid drying out of this coarser grade of sand and frequent desiccation of the grass was partly responsible for the poor stand of grass on these two mixtures.

Oven dry weights of roots could not be determined due to the contamination by the peat moss used in the mixtures, but based on data from the root development comparisons, there were no significant differences between replications which strengthens the methods used to compare root samples. Root depth was measured at the time of plugging but this was not considered in the evaluation of root quality since these measurements were compared in a separate analysis.

The term "root development" was used to describe the characteristics of root growth which included density, distribution and extensiveness of fibrousness of the root system.

Large significant differences existed between mixtures with the trend being toward more fully developed root systems in the higher sand content mixes. The graph in Plate VI illustrates this phenomenon. These data are in agreement with results reported by Loehwing (22) who observed more fibrous and highly developed root systems on plants in well aerated soils.

In the mason sand mixtures, root development increased as the percentages of sand increased from 75 to 100 percent, except in the 90 percent mason sand mixture, where all of the varieties indicated a decrease in root growth. Cohansey even showed a downward fluctuation in the 75 percent mason mixture.

Cohansey on the Kaw blow sand mixtures demonstrated its poorest root development in the 85 percent mixture, but all of the other grasses showed an

upward trend from 65 to 100 percent sand except Springfield which did not vary in the mixes containing from 65 to 85 percent blow sand. These data support observations made by Nelson (24) who reported bentgrass growing on 95 percent sand exhibited surface characteristics equal to grasses on a sandy loam but possessed better developed root zones. In comparing varieties, Penncross and Seaside were rated significantly over the stolonized varieties; however, no significance existed between Penncross and Seaside or between Cohansey and Springfield.

In the analysis of the data on root depth, each strip of grass was considered a separate variety; therefore, significant differences did exist between varieties as can be seen in the array of means in Table 13, but also there are significant differences between the two replications of grass. This difference between replications can be partly attributed to sampling error since half of the green was resampled later after finding a fault in the procedure.

Therefore, in making comparisons in Table 13, Penncross (6), Springfield (5), Cohansey (7) and Seaside (4) should be grouped and compared together and the remaining three which were on the other half of the green and sampled later should be compared separately.

Although these figures cannot be compared with any degree of confidence, the totals of the replications indicate the possibility of deeper root systems on Penncross, Seaside, Cohansey and then Springfield in descending order. These differences were not significant, however.

Some inferences may be gained from these data but, for the most part, variation in depth of roots was dependent upon the depth of the soil plug taken. Varying moisture levels and texture of the mixtures greatly influenced the ease of plugging and, consequently, the condition of the plug obtained.

In the higher sand content mixes in the mason group, the mixture failed to hold together and, therefore, a complete, intact plug $9\frac{1}{4}$ inches or 23 centimeters deep was not always recovered from the plot. If the bottom portion of the soil fell off, a shallower plug and thus a shorter root system was the result; whereas, on the 100 percent and other high sand content mixes many roots were pulled up which extended down into the mixture deeper than the soil plugger, some of which even extended into the gravel layer below the mixture. This accounts for some of the root systems being deeper than 23 centimeters and others only 19 and 20 centimeters deep.

The variation in root depth between grass varieties is largely due to error in sampling as can be seen by the variation between the two replications of Penncross and Cohansey. Nevertheless, much knowledge was gained concerning the distribution and depth of bentgrass roots the first season of growth.

This study initiates a continuing series whose objective is to record all visible differences which are worthy of consideration and which might add to the storehouse of information on this subject. Further differences are reflected in the condition in which the plots survived the first winter after planting. The green was watered occasionally during the winter months to prevent desiccation of the grass, however, some winter injury was evident on March 21 as the bentgrass resumed its growth. The most severe damage occurred on the 100 percent Blue mason sand plots, followed by 100 percent Kaw blow sand. The extent of damage was directly related to the percentages of sand in the mixtures. The most severe injury occurred to the Blue mason sand plots, with some of them being almost completely killed. The injury was less severe as the percent of sand decreased and there was very little injury to 85 and 75 percent sand plots and no injury was visible on the grass growing on 65 percent sand.

The primary cause of the injury was evidently drying of the sandy mixes and direct desiccation of the grasses, which was less noticeable on mixtures containing higher amounts of soil and organic matter. Among varieties, Carey suffered the most winter injury, followed by Springfield and Cohansey, all of which were stolonized. The seeded varieties of Penncross and Seaside were less severely damaged. These observations may be correlated with the evidence pointing toward deeper and better developed root systems on the seeded varieties. In contrast, on July 30 it was observed that the first strips to suffer from drying out and wilting were the seeded grasses, evidently then possessing shallower root systems than stolonized varieties. By the end of the season though, the root development of Penncross and Seaside had surpassed that of Cohansey and Springfield.

Penncross was the earliest variety to green up in the spring, while Springfield was the last one to resume growth.

An examination of the data in Table 14 concerning the mechanical analyses of the mixtures indicates a close relationship between the calculated percentages and the actual percentages of sand, silt and clay in the laboratory samples. In the calculated percentages the peat moss comprises from .51 to 1.74 percent of the weight; whereas, in the mechanical analysis, the organic matter is not measured. This small percentage is evidently distributed within the other fractions of sand, silt and clay.

In a comparison of the hydrometer method with the pipette method of mechanical analysis by Bouyoucos (3), the organic content of the soil did not interfere greatly with the results even though it was not destroyed with hydrogen peroxide prior to the analysis by the hydrometer method.

By comparing the calculations with the actual percentages obtained in the laboratory samples, it can readily be seen that the results from the

hydrometer method indicated, in most cases, more sand and less silt than was calculated. The clay content was usually a little higher than was expected.

In observing the soil columns during the mechanical analysis, the peat moss appeared to settle out with the sand, or between the sand and silt layers, which could easily affect the amounts of these two constituents. The finer particles of organic matter which remained in suspension longer could have increased the reading of the clay content to a small degree.

In comparing the field sample with the laboratory sample the immediate conclusion is that more soil or a volume of soil with a higher bulk density was used in the construction of the green than was used in the laboratory samples. This could have easily been possible since the stock pile of soil at the site of the green had settled somewhat during the winter, increasing the bulk density.

Therefore, the mechanical analysis data do not furnish an accurate indication of the exact volume proportions of the mixtures in the field, but the figures from the samples composed of sand and soil with a known bulk density represent a correlation which is quite close and indicates the possibility of using the Bouyoucos hydrometer method in estimating the proportions of sand, silt and clay which are incorporated into a golf green mixture, provided an analysis of the topsoil and sand used is available.

Very few workers have expressed the quantities of soil used in golf green mixtures in any other quantity than volume, due to the fact that it is the most common method of measuring. However, this measurement varies to a great extent depending on the bulk density of the particular soil.

Kunze (20) reported the amounts of soil in a desirable mixture ranged from 5 to 10 percent clay soil by volume or 2 to 4 percent by weight. The volume-weight comparisons of the soil in the laboratory mixtures in Table 15 indicate a somewhat heavier soil than was used by Kunze, but this could be

expected of a soil containing large amounts of silt and sand.

These soil analyses were an attempt to determine the proportions of sand, silt and clay in a golf green mixture and correlate these figures with current recommendations which are given in volume proportions.

SUMMARY AND CONCLUSIONS

Based on the observations of the five bentgrass varieties growing on ten different soil mixtures for one complete growing season, the following conclusions are suggested:

1. Stolonized grasses performed significantly better than seeded varieties, with Penncross being superior to Seaside.
2. Although no significant differences occurred between soil mixtures, 90 percent Kaw blow sand supported the most desirable putting surface, with 90 and 100 percent Blue mason sand mixtures being poorest.
3. Higher percentages of sand resulted in more extensively developed root systems with blow sand being more conducive to root development than mason sand.
4. Seeded varieties possessed more fully developed root systems than did stolonized grasses.
5. Winter injury attributed to desiccation of the grasses was most severe on the higher sand content mixtures, especially on the Blue mason sands, and was most noticeable on the stolonized varieties.

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LITERATURE CITED

(1) Anonymous. Green construction. Golfdom, September 1956, 30 (9):25-28.

(2) Beard, James B. The growth and development of Agrostis palustris roots as influenced by certain environmental factors. Master's thesis, 1959, Purdue University.

(3) Bouyoucos, G. J. A recalibration of the hydrometer method for making mechanical analysis of soils. Agron. Jour. 1951, 43:434-438.

(4) Brink, V. C. New techniques for the study of roots in place. Proc. 14th Annual Northwest Turf Conference, Washington State University 1960, pp. 25-28.

(5) Burton, Glenn W., E. H. DeVane and R. L. Carter. Root penetration, distribution and activity in southern grasses measured by yields, drought symptoms and P 32 uptake. Agron. Jour. May 1954, 46:229-33.

(6) Davis, Richard Richardson. The physical condition of putting green soils and other environmental factors affecting the quality of greens. Ph. D. Thesis, Purdue University, 1950.

(7) Dunning, Bob. Soil mixing for golf greens. Unpublished report presented at Central Plains Turf Conference, Kansas State University, October 1959.

(8) Ferguson, Marvin, Leon Howard and Morris E. Bloodworth. Laboratory methods for evaluation of putting green soil mixtures. USGA Journal and Turf Management, Sept. 1960, 13(5):30-32.

(9) Ferguson, Marvin H. Soils. USGA Journal and Turf Management, April 1959, 12(1):29-30.

(10) (________). When you build a putting green make sure the soil mixture is a good one. USGA Journal and Turf Management. Nov. 1955, 8(6):26-29.

(11) Fitts, O. B. Preliminary studies of the root growth of fine grasses under turf conditions. USGA Green Section 1925, 5:58-62.

(12) Frazier, Stephen Leslie. Turfgrass seedling development under measured environment and management conditions. Master's Thesis, Purdue University 1960.

(13) Garman, William L. Permeability of various grades of sand and peat and mixtures of these with soil and vermiculite. USGA Journal and Turf Management. April 1952, 5(1):27-28.

(14) Goss, Roy. Soils for heavy trafficked turf areas. Proceedings of the 14th Annual Northwest Turf Conference, Washington State University 1960, pp. 59-63.

(15) Graber, L. F. Food reserves in relation to other factors limiting the growth of grasses. Plant Physiology, January 1931, 6:43-72.

(16) Harrison, C. M. Effect of cutting and fertilizer application on grass development. Plant Phys. October 1931, 6:669-684.

(17) Holmes, James L. Factors in building a green. Golf Course Reporter, March-April 1959, 27(2):38-41.

(18) Howard, Hugh Leon. Response of some putting green soil mixtures to compaction. Master's Thesis, Texas A & M College 1959,

(19) Kunze, Raymond John. The effects of compaction of different golf green soil mixtures on plant growth. Master's Thesis, Texas A & M College, 1956.

(20) Kunze, Raymond John, M. H. Ferguson and J. B. Page. The effects of compaction on golf green mixtures. USGA Journal and Turf Management, November 1957, 10(6):24-27.

(21) Latham, James M. Jr. Trends in management practices in the southwest. USGA Journal and Turf Management, August 1959, 12(4):25-29.

(22) Loehwing, W. F. Physiological aspects of the effect of continuous soil aeration on plant growth. Plant Phys. July 1934, 9:567-83.

(23) Lunt, O. R. Minimizing compaction in putting greens. USGA Journal and Turf Management, Sept. 1956, 9(5):25-30.

(24) Nelson, Roy W. Toro field day. Golf Course Reporter. Nov.-Dec. 1957, 25(8):28-30.

(25) Pavlychenko, T. K. Quantitative studies of the entire root systems of weed and crop plants under field conditions. Ecology, January 1937, 18:62-79.

(26) (_______). The soil block washing in quantitative root study. Can. Jour. Res. February, 15(2):33-57.

(27) Richer, A. C. Progress Report. Pennsylvania Agric. Expt. Sta. September 1949.

(28) Roberts, Eliot C. and Evangel J. Bredakis. What, why, how of turf-grass root development. Golf Course Reporter, Nov-Dec. 1960, pp. 12-24.

(29) Robertson, J. H. Effect of frequent clipping on the development of certain grass seedlings. Plant Phys. July 1933, 8:425-447.

(30) Sprague, H. B. and J. F. Marrero. Effect of various sources of organic matter on properties of soils as determined by physical measurements and plant growth. Soil Science, 1930, 32(1):35-49.

(31) (_______), (_______). Further studies on the value of various types of organic matter for improving the physical condition of soils for plant growth. Soil Science, March 1932, 34:197-208.

(32) Sprague, H. B. Root development of perennial grasses and its relation to soil conditions. Soil Science 1933, 36(3):189-209.

(33) Stuckey, Irene. Seasonal growth of grass roots. American Journal Botany 1941, 28:486-491.

(34) Watson, James R. Jr. Irrigation and compaction on established fairway turf. Ph D. dissertation, Penn. State College, 1950.

(35) Weaver, John Ernest. Root development of field crops. McGraw-Hill Book Company, New York. 1926, 291 p.

ROOT AND TOP GROWTH STUDIES OF FIVE BENTGRASSES
ON TEN SOIL MIXTURES

by

JOHN C. PAIR

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It was the purpose of this investigation to evaluate 10 experimental soil mixtures and determine the sand-soil-peat ratio which was superior for the root and top growth of five bentgrass varieties.

The soil mixtures included in this test contained from 65 to 100 percent sand of two distinct grades, one a fine blow sand with 68 percent of its particles in the .25 to .5 millimeter size group, the other a coarser mason sand containing 49 percent of its particles in the .5 to 1.0 millimeter range.

The mixtures were placed 12 inches deep over a three inch layer of gravel for drainage and planted to bentgrass, Agrostis palustris, varieties Cohansey, Springfield, Carey, Penncross and Seaside.

Based on visual observations of the plots during the first growing season without any play on the green, the stolonized varieties Cohansey and Springfield were significantly better in putting surface quality than the seeded varieties of Penncross and Seaside, with Penncross being superior to Seaside.

An analysis of variance indicated no significant differences among soil mixtures at the end of the first season. However, significant differences did exist between mixtures at certain dates during the summer, with the mixture containing 90 percent Kaw blow sand rated best 13 out of 14 weeks, and frequently being superior to all the mason sand mixtures.

The 75 percent mason sand mixture exhibited the best putting surface of the coarse sand mixtures, with 90 and 100 percent Blue mason sand being the poorest mixtures on the green.

Root development was observed by sampling and washing the root systems of the grasses on all plots. Oven dry weights could not be determined due to

the contamination by the organic matter included in the mixtures. However, based on the density and distribution of roots, the root development was more extensive as the percent of sand increased, with the best development in the 100 percent blow sand. The seeded varieties were significantly better than the stolonized grasses in their root development.

Root depth was measured and varied between replications and varieties but was not significant between soil mixtures. Most of the root systems penetrated to a depth exceeding 23 centimeters, with evidence pointing toward deeper root systems on the seeded varieties.

Observations in the spring indicated some winter injury had occurred to the grass growing on the higher sand content mixtures, especially of the mason group, apparently caused by desiccation. The injury was most severe on the stolonized varieties which is in contrast to observations made during the summer when the seeded grasses were the first to suffer from drying out. This is further evidence pointing toward a deeper and better developed root system on the seeded varieties.

A mechanical analysis was conducted on samples of the mixtures in an attempt to correlate weight measurements with volume proportions.